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Mahler et al.

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(54) **MULTICHIP POWER SEMICONDUCTOR
DEVICE**

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H01L 24/05 (2013.01); *H01L 24/29* (2013.01);
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(58) **Field of Classification Search**

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H01L 2224/73265
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See application file for complete search history.

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(51) **Int. Cl.**

H01L 21/00 (2006.01)
H01L 21/768 (2006.01)

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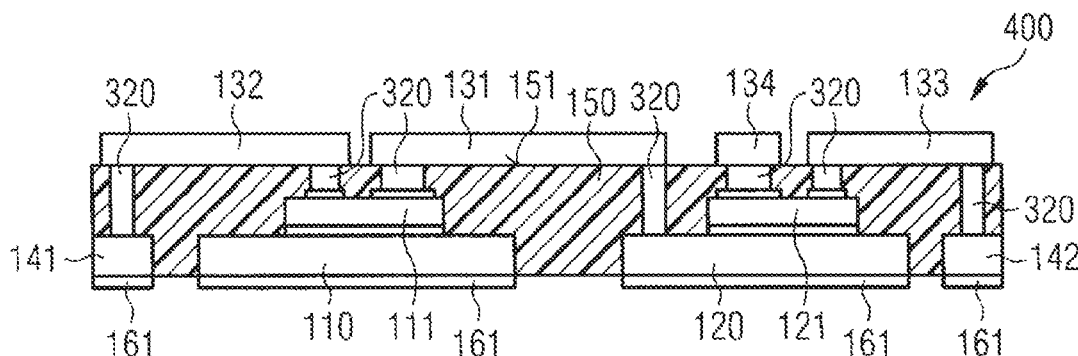
ABSTRACT

An electronic device includes a first chip carrier and a second chip carrier isolated from the first chip carrier. A first power semiconductor chip is mounted on and electrically connected to the first chip carrier. A second power semiconductor chip is mounted on and electrically connected to the second chip carrier. An electrically insulating material is configured to at least partially surround the first power semiconductor chip and the second power semiconductor chip. An electrical interconnect is configured to electrically connect the first power semiconductor chip to the second power semiconductor chip, wherein the electrical interconnect has at least one of a contact clip and a galvanically deposited conductor.

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CPC ... *H01L 21/76877* (2013.01); *H01L 21/76816*
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23/4334 (2013.01); *H01L 23/49513* (2013.01);
H01L 23/49517 (2013.01); *H01L 23/49524*
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23/49575 (2013.01); *H01L 23/49833*
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3 Claims, 10 Drawing Sheets



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FIG 1A

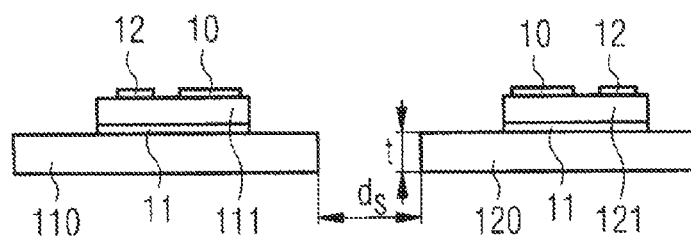


FIG 1B

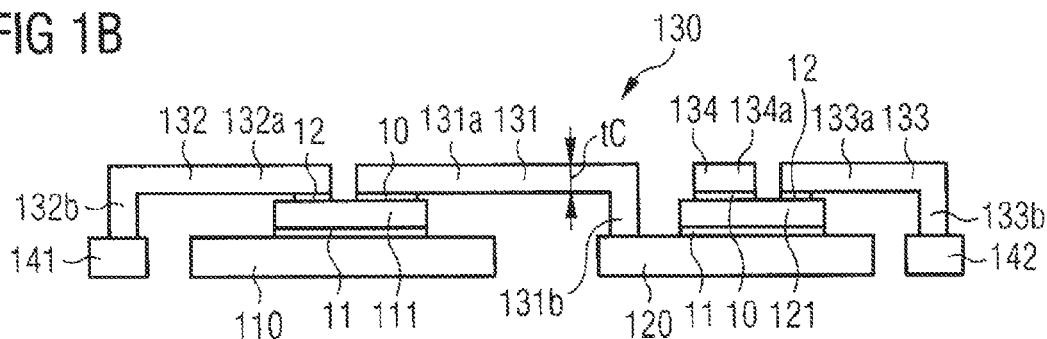


FIG 1C

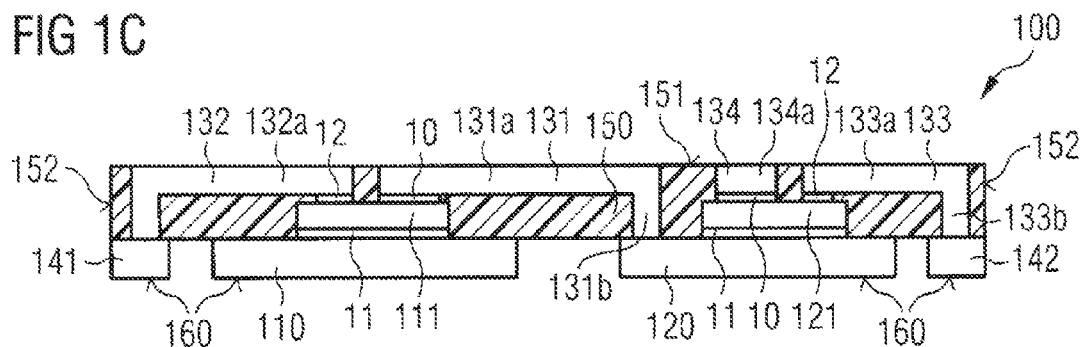


FIG 1D

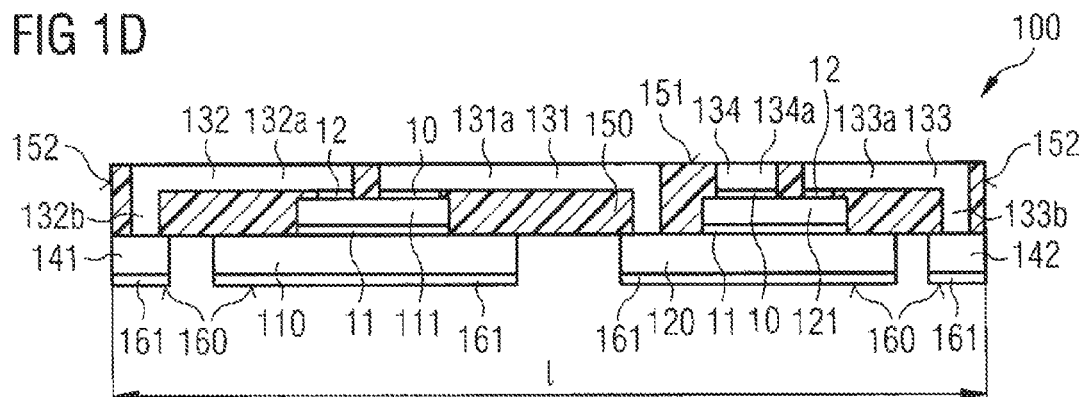


FIG 2A

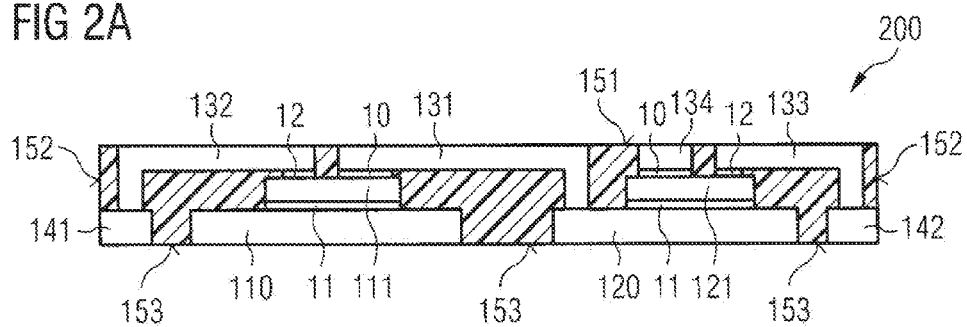


FIG 2B

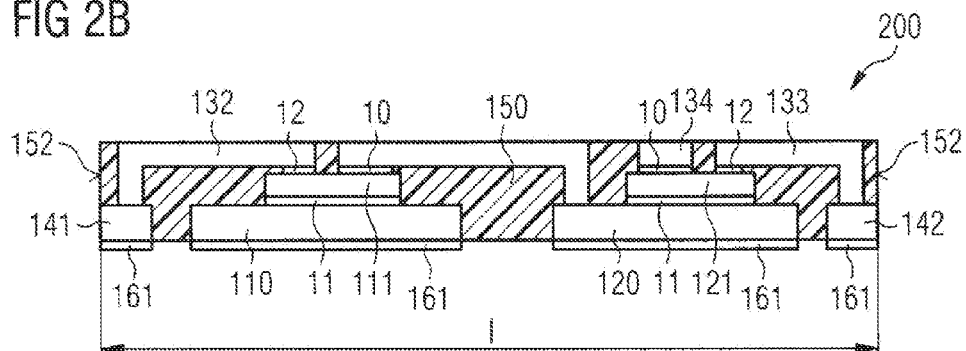


FIG 3A

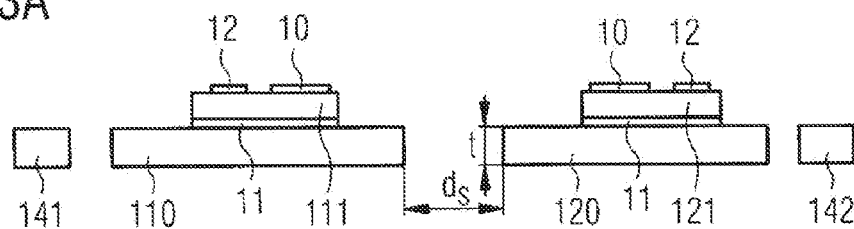


FIG 3B

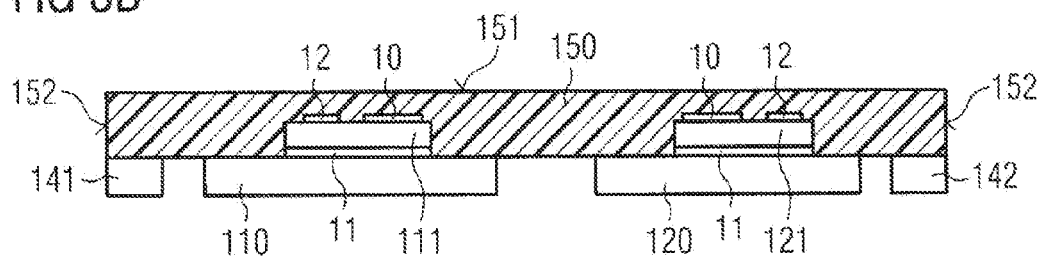


FIG 3C

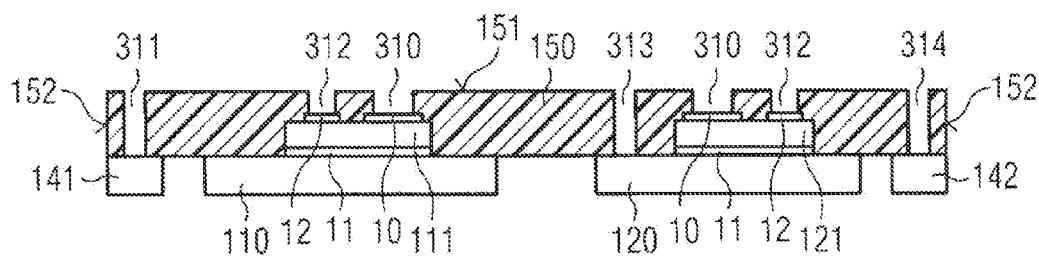


FIG 3D

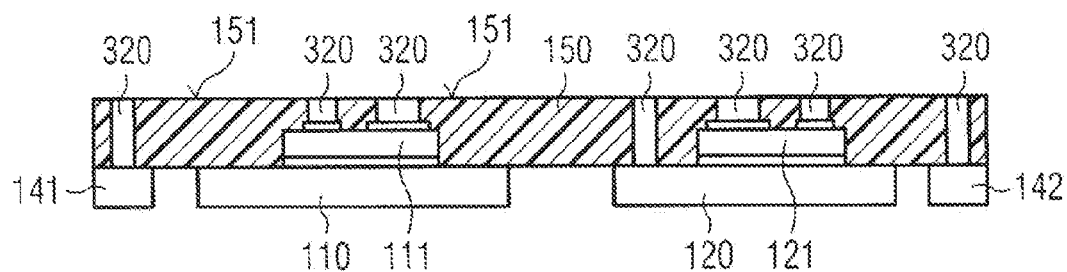


FIG 3E

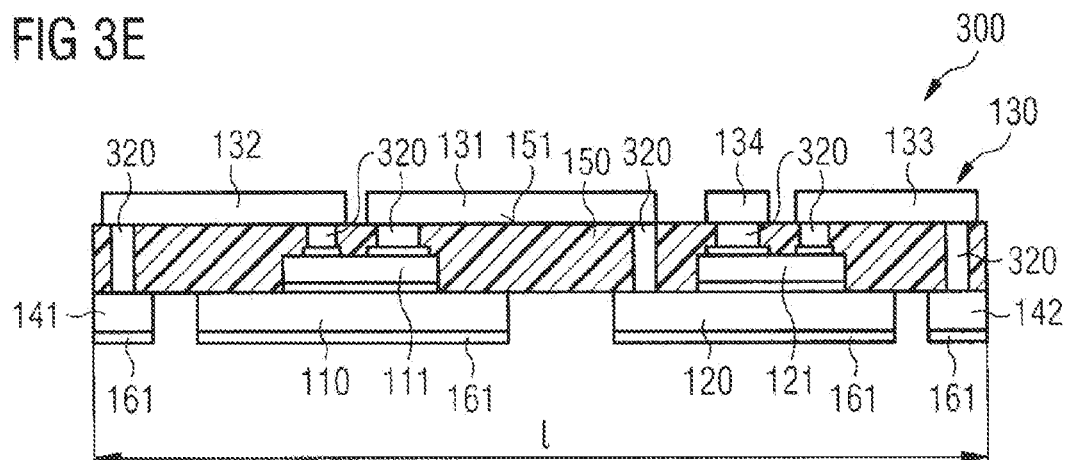


FIG 4

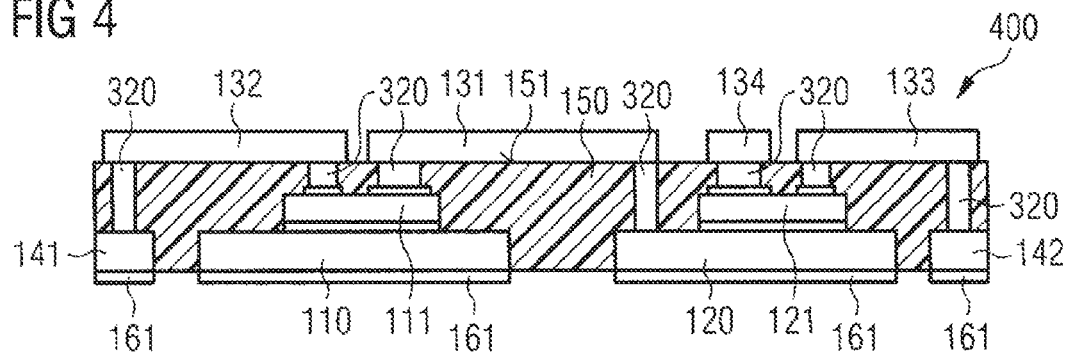


FIG 5A

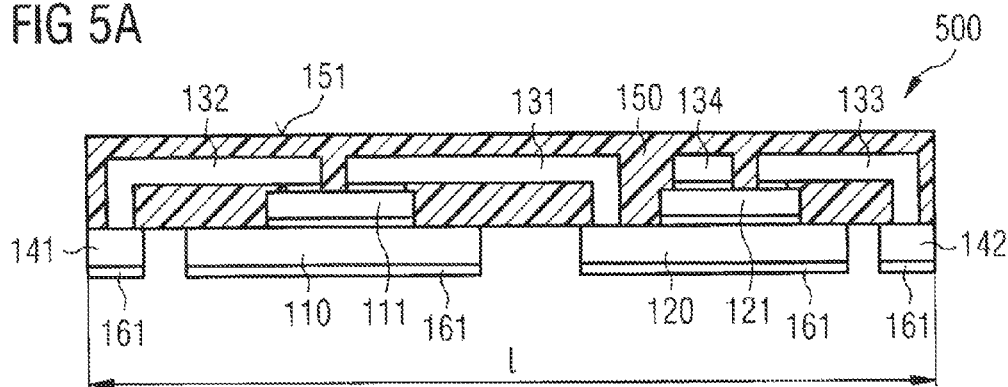


FIG 5B

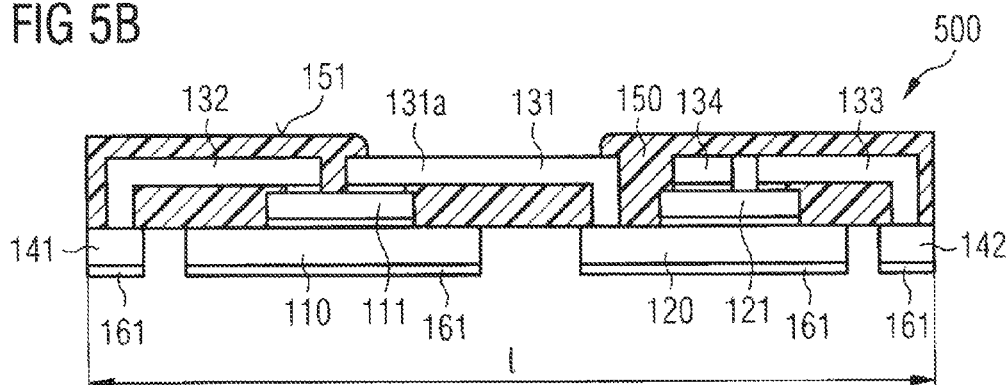


FIG 5C

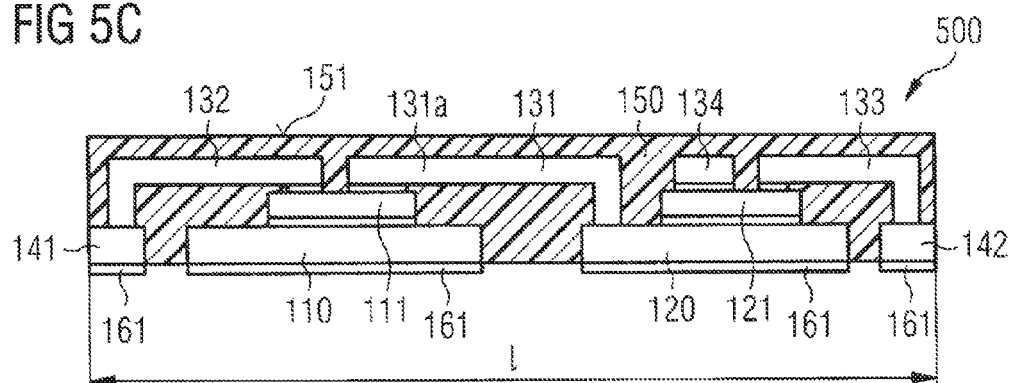


FIG 6A

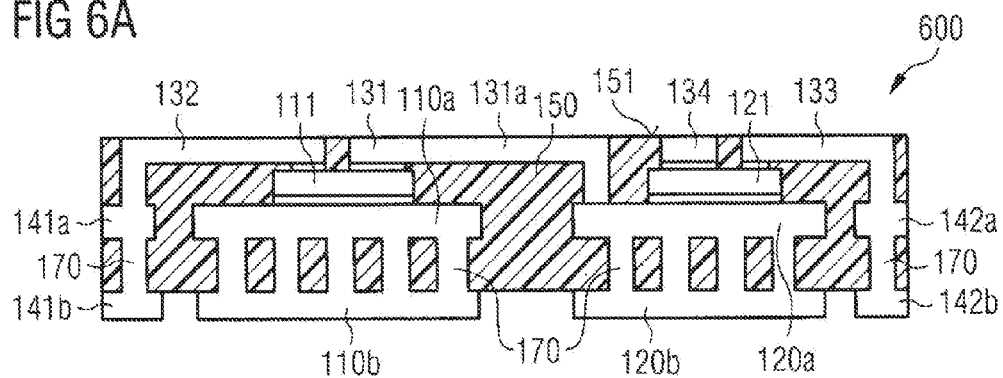


FIG 6B

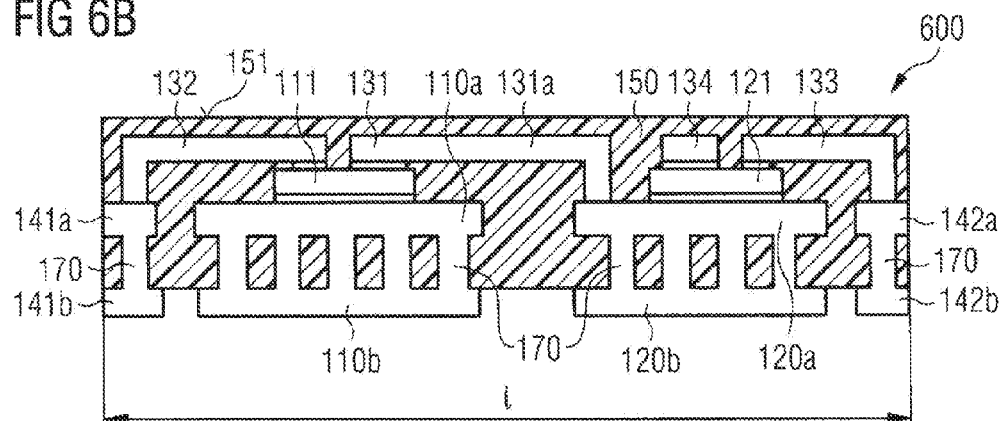


FIG 7A

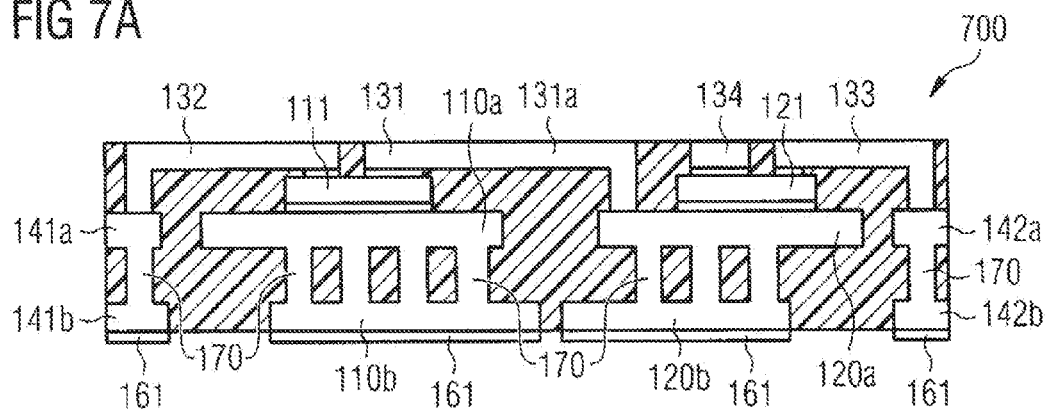


FIG 7B

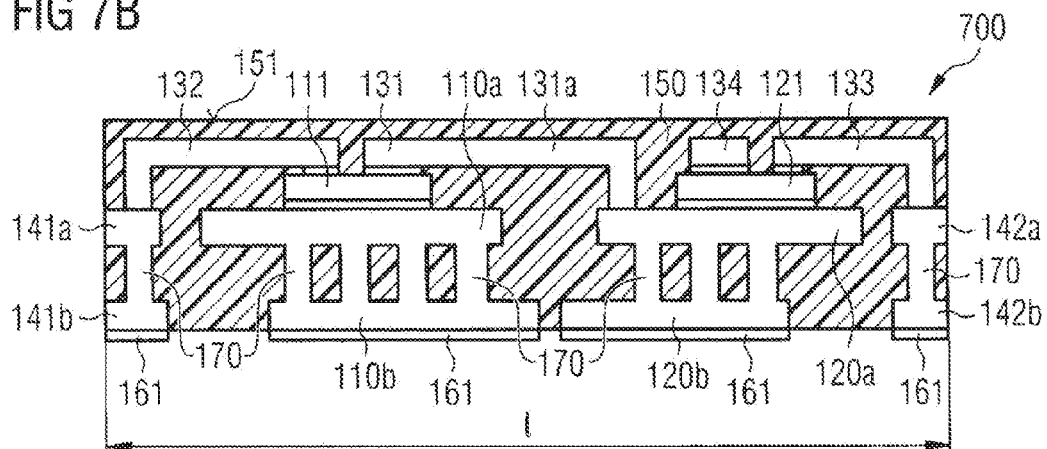


FIG 8

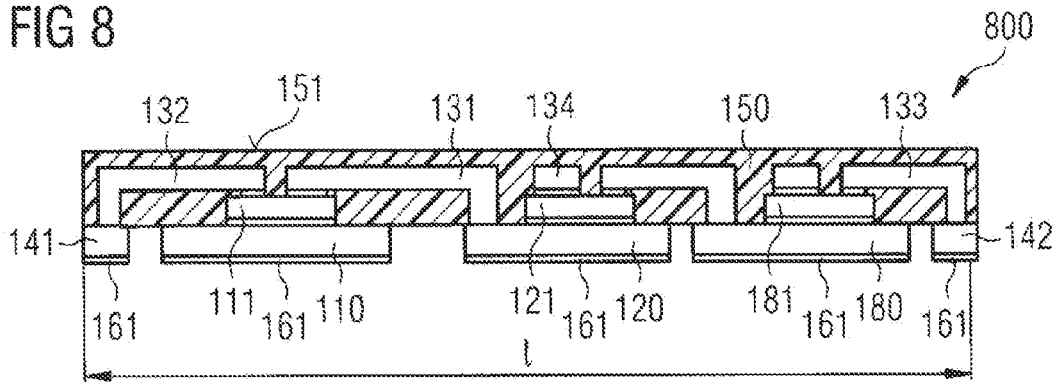


FIG 9

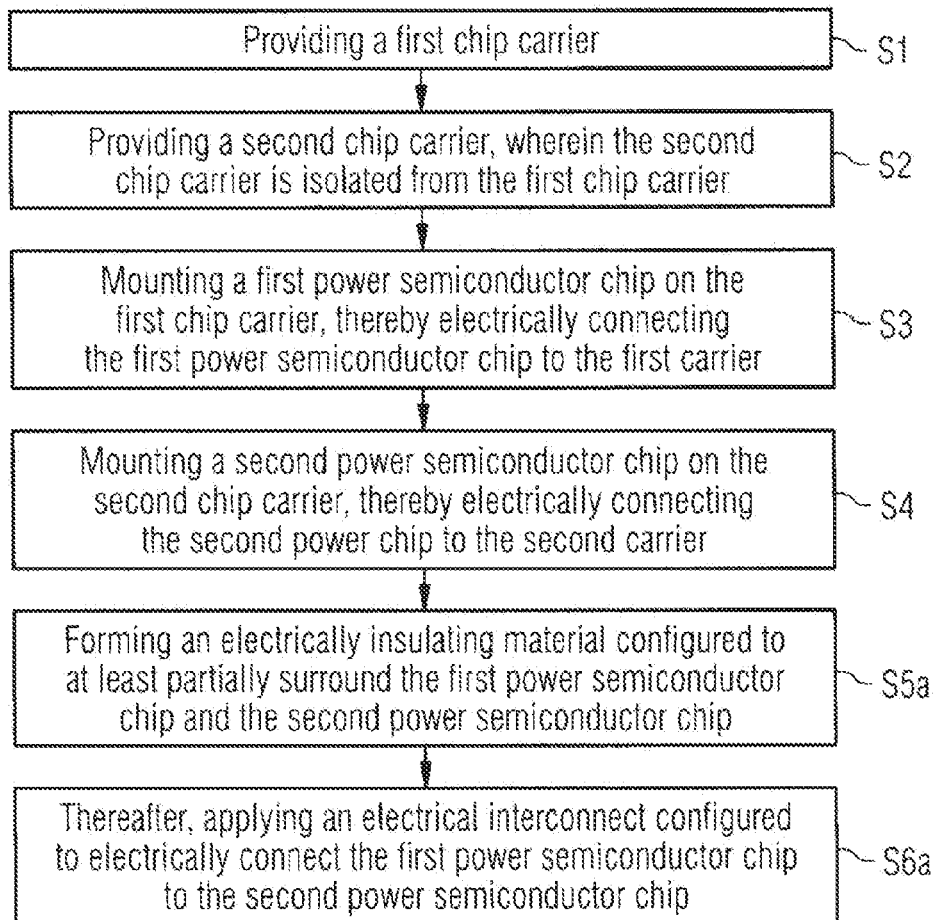


FIG 10

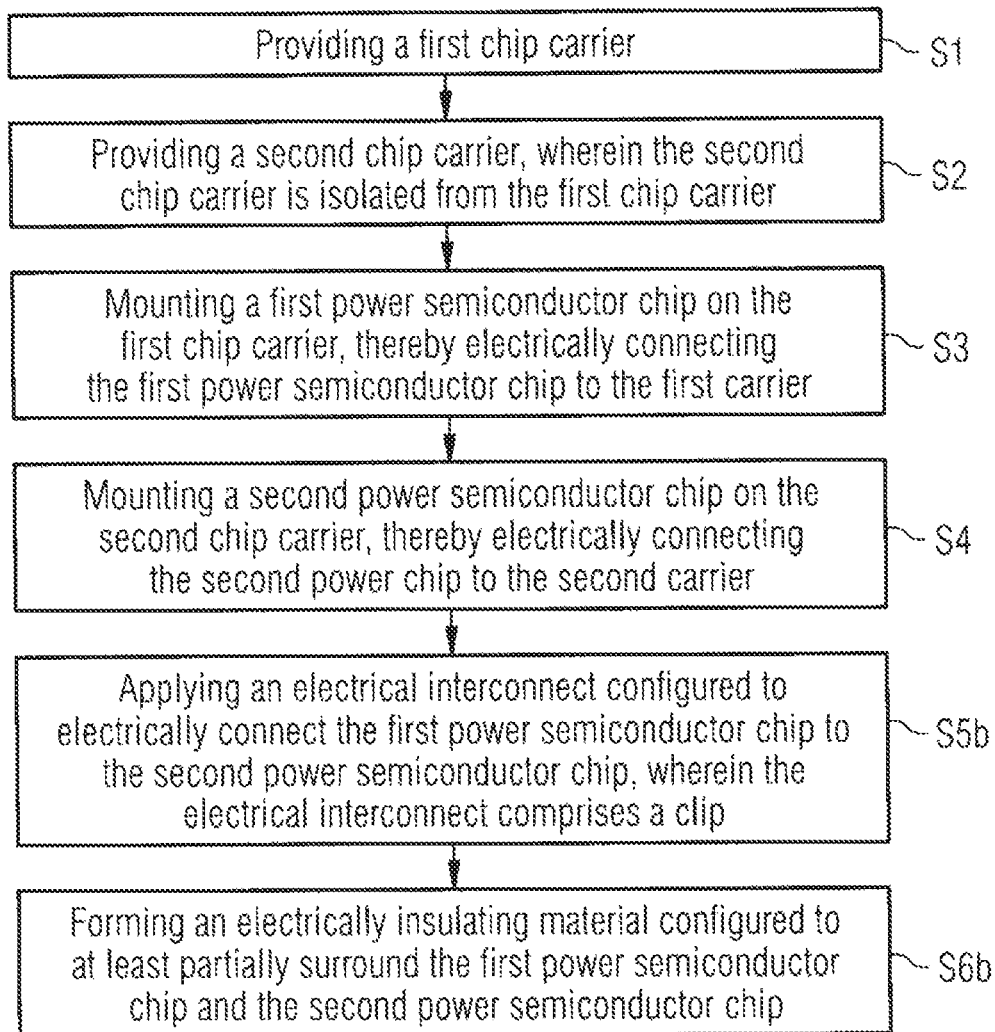
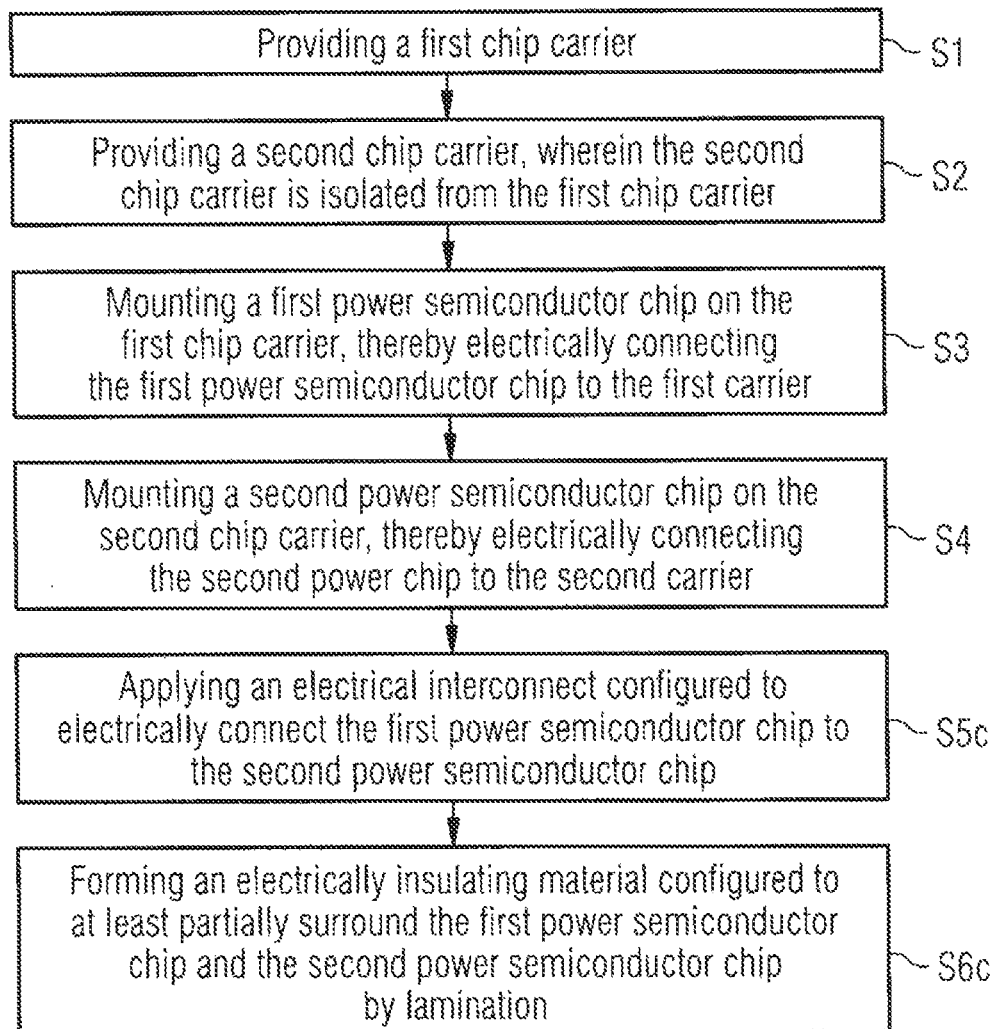


FIG 11



1

MULTICHIP POWER SEMICONDUCTOR DEVICE

The present application is a divisional of application Ser. No. 13/431,125 filed on Mar. 27, 2012, which is incorporated herein by reference.

TECHNICAL FIELD

The invention relates to electronic devices, and more particularly to the technique of packaging multiple power semiconductor chips.

BACKGROUND

Semiconductor device manufacturers are constantly striving to increase the performance of their products, while decreasing their cost of manufacture. A cost intensive area in the manufacture of semiconductor devices is packaging the semiconductor chips. As those skilled in the art are aware, integrated circuits are fabricated in wafers, which are then singulated to produce semiconductor chips. One or more semiconductor chips are placed in a package to protect them from environmental and physical stresses. Packaging also involves electrically connecting the semiconductor chips to a carrier and electrically interconnecting semiconductor chips mounted on the carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of embodiments and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and together with the description serve to explain principles of embodiments. Other embodiments and many of the intended advantages of embodiments will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

FIGS. 1A to 1D are sectional views schematically illustrating one embodiment of a method to produce an electronic device **100**;

FIGS. 2A and 2B are sectional views schematically illustrating one embodiment of a method to produce an electronic device **200**;

FIGS. 3A to 3E are sectional views schematically illustrating one embodiment of a method to produce an electronic device **300**;

FIG. 4 is a sectional view schematically illustrating one embodiment of an electronic device **400**;

FIGS. 5A to 5C are sectional views schematically illustrating embodiments of an electronic device **500**;

FIGS. 6A and 6B are sectional views schematically illustrating embodiments of an electronic device **600**;

FIGS. 7A and 7B are sectional views schematically illustrating embodiments of an electronic device **700**;

FIG. 8 is a sectional view schematically illustrating one embodiment of an electronic device **800**;

FIG. 9 is a flowchart illustrating a method of manufacturing an electronic device;

FIG. 10 is a flowchart illustrating a method of manufacturing an electronic device; and

FIG. 11 is a flowchart illustrating a method of manufacturing an electronic device.

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DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Aspects and embodiments are now described with reference to the drawings, wherein like reference numerals are generally utilized to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects of the embodiments. It may be evident, however, to one skilled in the art that one or more aspects of the embodiments may be practiced with a lesser degree of the specific details. In other instances, known structures and elements are shown in schematic form in order to facilitate describing one or more aspects of the embodiments. The following description is therefore not to be taken in a limiting sense, and the scope is defined by the appended claims. It should also be noted that the representations of the various layers, sheets or substrates in the figures are not necessarily to scale.

In the following description, reference is made to the accompanying drawings, which form a part thereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as e.g. “upper,” “lower,” “top,” “bottom,” “left-hand,” “right-hand,” “front side,” “backside,” etc., is used with reference to the orientation of the figures being described. Because components of embodiments can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention.

It is to be understood that the features of the various exemplary embodiments described herein may be combined with each other, unless specifically noted otherwise.

As employed in this specification, the terms “coupled” and/or “electrically coupled” are not meant to mean that the elements must be directly coupled together. Intervening elements may be provided between the “coupled” or “electrically coupled” elements.

Devices containing power semiconductor chips are described below. In particular, power semiconductor chips having a vertical structure may be involved, that is to say that the power semiconductor chips may be fabricated in such a way that electric currents can flow in a direction perpendicular to the main surfaces of the power semiconductor chips. A power semiconductor chip having a vertical structure has contact pads or electrodes on its two main surfaces, that is to say on its top side and bottom side. Furthermore, the electronic devices described herein may include logic integrated circuits to control the power semiconductor chips.

Vertical power semiconductor chips may, for example, be configured as power MOSFETs (Metal Oxide Semiconductor Field Effect Transistors), IGBTs (Insulated Gate Bipolar Transistors), JFETs (Junction Gate Field Effect Transistors), power bipolar transistors or power diodes. By way of example, the source contact pad and the gate contact pad of a power MOSFET may be situated on one main surface, while the drain contact pad of the power MOSFET may be arranged on the other main surface.

The contact pads serve for electrically contacting the power semiconductor chips or circuits integrated in the power semiconductor chip. The contact pads may have the form of lands, i.e., flat contact layers on an outer surface of the power semiconductor chip. The contact pads may com-

prise or be made of any desired metal or metal alloy, for example, aluminum, titanium, gold, silver, copper, palladium, platinum, nickel, chromium or nickel vanadium. The metal layers need not be homogenous or manufactured from just one material, that is to say various compositions and concentrations of the materials contained in the metal layers are possible.

The power semiconductor chips may be manufactured from specific semiconductor material such as, for example, Si, SiC, SiGe, GaAs, GaN, etc., and, furthermore, may contain inorganic and/or organic materials that are not semiconductors. The power semiconductor chips may be of different types and may be manufactured by different technologies.

One or more power semiconductor chips may be mounted on each of the at least two chip carriers and are at least partly surrounded or embedded in at least one electrically insulating material. The electrically insulating material may be a mold material or may have the shape of a layer, e.g., a sheet or foil, that is laminated on top of the power semiconductor chips and the chip carriers.

The electrically insulating material may comprise or be made of a thermoset material or a thermoplastic material. A thermoset material may, e.g., be made on the basis of an epoxy resin. A thermoplastic material may, e.g., comprise one or more materials of the group of polyetherimide (PEI), polyether-sulfone (PES), polyphenylene-sulfide (PPS) or polyamide-imide (PAI). Thermoplastic materials melt by application of pressure and heat during molding or lamination and (reversibly) harden upon cooling and pressure release.

The electrically insulating material may comprise or be made of a polymer material. The electrically insulating material may comprise at least one of a filled or unfilled mold material, a filled or unfilled thermoplastic material, a filled or unfilled thermoset material, a filled or unfilled laminate, a fiber-reinforced laminate, a fiber-reinforced polymer laminate, and a fiber-reinforced polymer laminate with filler particles.

In one embodiment, the electrically insulating material may be a laminate, e.g., a polymer foil or sheet. Heat and pressure may be applied for a time suitable to attach the polymer foil or sheet to the underlying structure. During lamination, the electrically insulating foil or sheet is capable of flowing (i.e., is in a plastic state), resulting in that gaps between the power semiconductor chips and/or other topological structures on the chip carriers are filled with the polymer material of the electrically insulating foil or sheet. The electrically insulating foil or sheet may comprise or be made of any appropriate thermoplastic or thermoset material. In one embodiment, the insulating foil or sheet may comprise or be made of a prepreg (short for pre-impregnated fibers), that is, e.g., made of a combination of a fiber mat, for example, glass or carbon fibers, and a resin, for example, a thermoset or thermoplastic material. Prepreg materials are known in the art and are typically used to manufacture PCBs (printed circuit boards). Further, in one embodiment, the laminate may comprise or be made of a polymer material which is coated with a metal layer, e.g., a copper layer, i.e., a so-called RCC (Resin Coated Copper) foil.

The at least two chip carriers on each of which at least one power semiconductor chip is mounted form a part of the electronic device. In one embodiment, each chip carrier may be a metal plate or sheet such as, e.g., a die pad of a leadframe. Each power semiconductor chip may be mounted on a main surface of the associated chip carrier.

In other embodiments, one or more of the chip carriers may be made of plastics or ceramics. For instance, the chip carriers may comprise a layer of plastics coated with a metal layer. By way of example, such chip carriers may be a single-layer PCB or a multi-layer PCB. The PCB may have at least one insulating layer and a structured metal foil layer attached to the insulating layer. The insulating layer is typically made on the basis of epoxy resin, polytetrafluoroethylene, aramid fibers or carbon fibers and may include reinforcement means such as fiber mats, for example, glass or carbon fibers. In other embodiments, the chip carrier may comprise a plate of ceramics coated with a metal layer. By way of example, such chip carriers may be DCB (direct copper bonded) ceramics substrates.

A variety of different types of electronic devices may be produced by the techniques described herein. By way of example, an electronic device according to one embodiment may constitute a power supply containing two or more power MOSFETs and, optionally, one or more logic integrated circuits. For instance, an electronic device disclosed herein may comprise a half-bridge circuit, optionally including a logic integrated circuit chip as a driver. A half-bridge circuit may, e.g., be implemented in electronic circuits for converting DC voltages, so-called DC-DC converters. DC-DC converters may be used to convert a DC input voltage provided by a battery or rechargeable battery into a DC output voltage matched to the demands of electronic circuits connected downstream.

FIGS. 1A-1D illustrate by way of example process stages of one embodiment of a method of producing an electronic device 100. It is to be noted that the stages of production illustrated in FIGS. 1A-1D may be understood as simplifications, since further steps may be used which are not depicted in these figures. For instance, further dielectric layers or structured metal layers may be applied during the assembly of the electronic device 100. Further, electrically conducting wires may be generated on the electrically insulating material to electrically connect one or more contact pads of the power semiconductor chips to outer terminals of the electronic device 100. Some of the possible variations are explained further below in conjunction with embodiments shown in FIGS. 2A-8.

According to FIG. 1A, a first chip carrier 110 and a second chip carrier 120 may be provided. The first chip carrier 110 and/or the second chip carrier 120 may comprise or be made of a flat metal plate, e.g., a die pad of a leadframe. In other embodiments the first and/or second chip carrier 110, 120 may each comprise or be made of a plastic plate or ceramic substrate coated by a metal layer on the upper surface thereof.

First chip carrier 110 and second chip carrier 120 may be isolated from each other, e.g., each chip carrier 110, 120 may be insular. They may be separated from each other by a separation distance d_s . Separation distance d_s may range from about 10 μm to about 10 mm, e.g. from about 50 μm to about 5 mm, e.g. from about 100 μm to about 1 mm.

First chip carrier 110 and/or second chip carrier 120 may have a thickness t ranging from about 50 μm to about 1500 μm , e.g., about 100 μm to about 500 μm , e.g., 150 μm to about 300 μm .

A first power semiconductor chip 111 is mounted on and electrically connected to an upper surface of the first chip carrier 110. Simultaneously or sequentially, a second power semiconductor chip 121 is mounted on and electrically connected to an upper surface of the second chip carrier 120.

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The thickness (i.e., height) of the power semiconductor chips **111**, **121** may be less than 500 μm , 300 μm , 200 μm , 100 μm and, in particular, less than 60 or even 40 or 20 μm .

Each one of the first and second power semiconductor chips **111**, **121** is mounted on the respective chip carrier **110**, **120** with its bottom surface facing the respective chip carrier (e.g., die pad of a leadframe) **110**, **120** and its top surface facing away from the respective chip carrier (e.g., die pad of a leadframe) **110**, **120**. Each one of the first and second power semiconductor chips **111**, **121** may have a first contact pad **10** on the top surface and a second contact pad **11** on the bottom surface. The first and second contact pads **10**, **11** may be load contact pads. Furthermore, each one of the first and second power semiconductor chips **111**, **121** may have a third contact pad **12** on its top surface. The third contact pad **12** may be a control contact pad.

Each one of the first and second power semiconductor chips **111**, **121** may be configured as a power transistor, for example, a power MOSFET, IGBT, JFET or power bipolar transistor, or a power diode. In the case of a power MOSFET or a JFET, a first contact pad **10** is a source contact pad, the second contact pad **11** is a drain contact pad, and the third contact pad **12** is a gate contact pad. In the case of an IGBT, the first contact pad **10** is an emitter contact pad, the second contact pad **11** is a collector contact pad, and the third contact pad **12** is a gate contact pad. In the case of a power bipolar transistor, the first contact pad **10** is an emitter contact pad, the second contact pad **11** is a collector contact pad, and the third contact pad **12** is a base contact pad. In the case of a power diode, the first and second contact pads **10**, **11** are cathode and anode, respectively, and there is no third contact pad. During operation, voltages higher than 5, 50, 100, 500 or 1000 V may be applied between the first and second contact pads **10**, **11**. The switching frequency applied to the third contact pad **12** may be in the range from 1 kHz to 100 MHz, but may also be outside of this range.

The second contact pad **11** may be electrically and mechanically coupled to the upper surface of the respective chip carrier **110**, **120** by a bond layer (not shown). The bond layer may, e.g., comprise or consist of solder, a soft solder, a diffusion solder, a paste, a nanopaste, or an electrically conductive adhesive.

More specifically, the bond layer may, e.g., be made of a diffusion soldering material such as, e.g., AuSn, AgSn, CuSn, AgIn, AuIn, CuIn, AuSi, Sn or Au, or by a paste containing metal particles distributed in a polymer material or resin such as, e.g., α -terpineol. Pastes containing metal particles can, for example, be purchased from the companies Coocon Electronic (product name: N 1000), Advanced Nano-Particles (ANP), Harima Chemicals (product names: NPS-H and NHD-1) or NBE Technologies (product name: NBE Tech). The metal particles may, for example, be made of silver, gold, copper, tin or nickel. The extensions (average diameter) of the metal particles may be smaller than 100 nm and, in particular, smaller than 50 nm or 10 nm. These pastes are also referred to as nanopastes in the art.

According to FIG. 1B, an electrical interconnect **130** may be applied to the structure shown in FIG. 1A. The electrical interconnect **130** may comprise a first electrical interconnect **131** configured to electrically connect the first power semiconductor chip **111** to the second power semiconductor chip **121**. More specifically, the first electrical interconnect **131** may be formed such that it electrically connects the first contact pad **10** of the first power semiconductor chip **111** to the second chip carrier **120**, wherein the second chip carrier **120** is electrically connected to the second contact **11** pad of the second power semiconductor chip **121**.

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The electrical interconnect **130** may comprise a second electrical interconnect **132** configured to electrically connect the first power semiconductor chip **111** to a first lead **141**. The electrical interconnect **130** may comprise a third electrical interconnect **133** configured to electrically connect the second power semiconductor chip **121** to a second lead **142**. The electrical interconnect **130** may comprise a fourth electrical interconnect **134** configured to be electrically connected to the first contact pad **10** of the second power semiconductor chip **121**.

The first lead **141** and/or the second lead **142** may form part of a leadframe. The leadframe may comprise the first chip carrier **110** and the second chip carrier **120** to form die pads of the leadframe. The first lead **141** may be isolated from the first chip carrier **110**, the second chip carrier **120** and the second lead **142**. Similarly, the second lead **142** may be isolated from the second chip carrier **120**, the first chip carrier **110** and the first lead **141**.

The first electrical interconnect **131** may comprise a first section **131a** extending substantially in a direction parallel to a plane defined by the first chip carrier **110** and/or the second chip carrier **120**, and a second section **131b** extending substantially in a direction perpendicular to this plane, i.e., perpendicular to the first section **131a**. The first section **131a** may be electrically connected to the first power semiconductor chip **111** and the second section **131b** may be electrically connected to the second chip carrier **120** and, via the second chip carrier **120**, to the second power semiconductor chip **121**. By way of example, if the first power semiconductor chip **111** and the second power semiconductor chip **121** are MOSFETs, the first section **131a** may connect to the source contact pad **10** of the first power semiconductor chip **111** and the second section **131b** may connect to the drain contact pad **11** of the second power semiconductor chip **121**. In one embodiment, the first section **131a** may, e.g., have a thickness t_c in the range from about 50 to 300 μm , in particular 100 to 200 μm .

The second, third and fourth electrical interconnects **132**, **133**, **134** may have a shape similar to the shape of the first electrical interconnect **131**, i.e., may be composed of first sections **132a**, **133a**, **134a** and second sections **132b**, **133b**, with the second sections **132b**, **133b** being oriented perpendicular to the first sections **132a**, **133a**, **134a**, respectively.

If the first and second power semiconductor chips **111**, **121** are MOSFETs, the first sections **132a**, **133a** of the second and third electrical interconnects **132**, **133** may be connected to the gate contact pads **12** of the first and second power semiconductor chips **111**, **121** and the second sections **132b**, **133b** of the second and third electrical interconnects **132**, **133** may be connected to the first and second leads **141**, **142**, respectively. The first section **134a** of the fourth electrical interconnect **134** may be connected to the source contact pad **10** of the second power semiconductor chip **121**. The fourth electrical interconnect **134** may extend in a direction perpendicular to the sectional plane of FIGS. 1A-1D.

The first electrical interconnect **131** may be firmly secured to the first contact pad **10** of the first power semiconductor chip **111** and to the second chip carrier **120** by means of an electrically conductive bonding material, e.g., a solder, a soft solder, a diffusion solder, a paste, a nanopaste, an electrically conductive glue, etc. Similarly, the second, third and electrical interconnects **132**, **133**, **134** may be secured to the corresponding parts mentioned above using one or more of these electrically conductive bonding materials.

The first electrical interconnect **131** may be made of one integral part having, e.g., an L-shape as shown in FIG. 1B.

Similarly, second, third and fourth electrical interconnects **132**, **133**, **134** may each be made of one integral part having e.g. an L-shape as shown in FIG. 1B.

The first electrical interconnect **131** may, e.g., be a contact clip. The contact clip may be manufactured from a metal or a metal alloy, in particular, copper, copper alloys, iron nickel or other appropriate electrically conductive materials. The shape of the contact clip is not limited to any size or geometric shape. The contact clip may have the shape as exemplarily illustrated in FIG. 1B. The contact clip may be fabricated by stamping, punching, pressing, cutting, sawing, milling, etching or any other appropriate technique. Alternatively, the first electrical interconnect **131** may, e.g., be an electrically conductive bond wire.

The first, second, third and fourth electrical interconnect **131**, **132**, **133**, **134** may comprise or be made of any desired metal, for example, Cu, Ni, NiSn, Zn, Bi, Au, Ag, Pt, Pd, or any alloy of one or more of these metals.

In FIG. 1C an electrically insulating material **150** may be applied. The insulating material **150** may be applied to overlay at least partly one or both of the first and second chip carriers **110**, **120** and at least partly one or both of the first and second power semiconductor chips **111**, **121**.

Electrically insulating material **150** may be arranged to at least partly surround the first power semiconductor chip **111** and to at least partly surround the second power semiconductor chip **121**.

Electrically insulating material **150** may be applied between the first power semiconductor chip **111** and the second power semiconductor chip **121**. Electrically insulating material **150** may be applied to at least partially cover the lower surfaces of one or more of the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134**, the lower surfaces being the surfaces facing the first and second chip carriers **110**, **120**. Electrically insulating material **150** may be applied to cover side surfaces of one or more of the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134** facing away from the first and second chip carriers **110**, **120**. In particular, the upper surface of the first section **131a** of the first electrical interconnect **131** may partly or fully be uncovered by the electrically insulating material **150**. Similarly, the upper surfaces of the first sections **132a**, **133a**, **134a** of the second, third and fourth electrical interconnects **132**, **133**, **134** may be partially or fully be uncovered by the electrically insulating material **150**. These partially or fully uncovered upper interconnect surfaces may represent external-facing outer surfaces of electronic devices **100** as shown in FIGS. 1C and 1D.

Further, the electrically insulating material **150** may cover outward-facing side faces of the second sections **131b**, **132b**, **133b** of the electrical interconnect **130**. That way, external-facing outer side surfaces **152** of the electronic device **100** may partly or fully be formed by electrically insulating material **150**. According to FIG. 1C, a portion of the external-facing outer side surface **152** extending above the upper surface of the first and second leads **141**, **142** may be formed by electrically insulating material **150**. In other implementations not illustrated herein, also the external-facing outer side surfaces of the first and second leads **141**, **142** may be covered by electrically insulating material **150**.

The electrically insulating material **150** may, e.g., be applied by using molding techniques. Various molding tech-

niques such as, e.g., compression molding, injection molding, transfer molding, powder molding or liquid molding may be applied.

The electrically insulating material **150** may, e.g., be applied by using lamination techniques as described above.

According to FIG. 1D, the bottom surfaces of the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** may be coated by a solderable coating **161**. The coating **161** may also be referred to as plating or final finish. The coating **161** may assist soldering the electronic device **100** to a PCB or any other board used, e.g., by a customer to mount the electronic device **100**. The coating **161** may, e.g., comprise a material consisting of one or more of Ni, Au, NiPd, NiAu, NiPdAu and NiPdAuAg alloy.

The first chip carrier **110** and the second chip carrier **120** may be arranged substantially level with each other. The first power semiconductor chip **111** and the second power semiconductor chip **121** may be arranged substantially level with each other. The upper surfaces of the first sections **131a**, **132a**, **133a**, **134a** may be arranged substantially level with each other. They may also be arranged substantially level with the external-facing upper surface **151** of electrically insulating material **150**.

The whole electronic device **100** as shown in FIG. 1C or 1D may have a length **1** from about 1 mm to 50 mm, e.g., about 2 mm to 20 mm, and a width (extending in a direction perpendicular to the sectional plane) from about 1 mm to 50 mm, e.g., about 2 mm to about 20 mm. The lateral dimensions of the leadframe including first and second leads **141**, **142** and first and second chip carriers **110**, **120** may have the same values.

The electronic device **100** as shown in FIG. 1C or 1D may use the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** as external contact elements (or external contact pads), which may be of any shape and size. The external contact elements may be accessible from outside the electronic device **100** and may thus allow electrical contact to be made with the power semiconductor chips **111**, **121** from outside the electronic device **100**. For this reason, the external contact elements may have external contact surfaces **160** which can be accessed from outside the device.

According to FIG. 1C, the exposed bottom surfaces of the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** may form external contact surfaces **160** of the electronic device **100**. According to FIG. 1D, the exposed bottom surfaces of the coating **161** may form the external contact surfaces **160** of the electronic device **100**.

The external contact elements, e.g., the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** may be thermally conductive and may serve as heat sinks for dissipating heat generated by the power semiconductor chips **111**, **121**.

When the electrical interconnect **130** comprises one or more sections **131a**, **132a**, **133a**, **134a** being uncovered by the electrically insulating material **150**, these exposed sections **131a**, **132a**, **133a**, **134a** may serve as heat sinks for dissipating heat generated by the power semiconductor chips **111**, **121**.

FIGS. 2A and 2B exemplify stages of a method of manufacturing an electronic device **200**. The electronic device **200** of FIG. 2A corresponds to the electronic device **100** of FIG. 1C with the exception that gaps or recesses between the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** are filled by electrically insulating material **150**. Generally, external contact elements of the electronic device **200** such as, e.g., the first carrier **110**,

the second carrier **120**, the first lead **141**, and the second lead **142** may partly or completely be surrounded by insulating material **150**.

The bottom surfaces of the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** may level with the bottom surface **153** of the electrically insulating material **150** within the gaps or recesses between the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142**.

Analogously, these gaps or recesses are filled with electrically insulating material **150** in the electronic device **200** shown in FIG. 2B. Here, the bottom surfaces of the first carrier **110**, the second carrier **120**, the first lead **141**, and the second lead **142** may be coated by solderable coatings **161** corresponding to electronic device **100** illustrated in FIG. 1D.

In some implementations not depicted in the figures, also the external-facing side surfaces of the first and second leads **141** and **142** or, more generally, of external contact elements defining an outline of the footprint of the electronic devices **100**, **200** may be covered by electrically insulating material **150**.

All disclosure including techniques, methods, materials and dimensions as described above in conjunction with FIGS. 1A-1D may be used to manufacture the electronic devices **200** shown in FIG. 2A or 2B. Reference is made to this disclosure to avoid reiteration.

FIGS. 3A-3E illustrate stages of a process of manufacturing a semiconductor device **300**. In FIG. 3A, the first carrier **110**, the second carrier **120**, e.g. the first lead **141** and, e.g., the second lead **142** may be provided.

As described in more detail above, the first power semiconductor chip **111** is mounted on and electrically connected to the first carrier **110** and the second power semiconductor chip **121** is mounted on and electrically connected to the second chip carrier **120**.

In FIG. 3B the electrically insulating material **150** is applied over the first carrier **110**, the second carrier **120**, the first power semiconductor chip **111**, the second power semiconductor chip **121** and may, e.g., be also applied over the first lead **141** and the second lead **142**. All techniques of applying the electrically insulating material **150** as described above may be employed, e.g. lamination, molding etc.

According to FIG. 3C, openings **310**, **311**, **312**, **313**, **314** may be formed in the external-facing outer surface **151** of the electrically insulating material **150**. Opening **311** may be formed to expose an area of the first lead **141**, opening **313** may be formed to expose an area of the second chip carrier **120** and opening **314** may be formed to expose an area of the second lead **142**. Further, openings **310** may be formed to expose areas of the first contact pads **10** of the first and second power semiconductor chips **111**, **121** and openings **312** may be formed to expose areas of the third contact pads **12** of the first and second power semiconductor chips **111**, **121**.

The openings **310**, **311**, **312**, **313**, **314** may be formed, for instance, by conventional drilling, laser drilling, chemical etching or any other appropriate method. The width of the openings **310**, **311**, **312**, **313**, **314** in the lateral direction may, for example, be in the range from about 20 to 300 μm .

As exemplified in FIG. 3D, the openings **310**, **311**, **312**, **313**, **314** may then be filled by an electrically conductive material **320**. For instance, the openings **310**, **311**, **312**, **313**, **314** may be made conductive by galvanic plating techniques. Further, it is also possible to fill the openings **310**, **311**, **312**, **313**, **314** with a material consisting of a paste containing metal particles. As a result, the electrically con-

ductive material **320** in openings **310**, **311**, **312**, **313**, **314** is electrically connected to the exposed areas of the first lead **141**, the second lead **142**, the second chip carrier **120**, the first contact pads **10**, and the third contact pads **12**. Conductive openings **310**, **311**, **312**, **313**, **314** are also referred to as vias (vertical interconnect access) herein.

As illustrated in FIG. 3E, after filling the openings **310**, **311**, **312**, **313**, **314**, the electrical interconnect **130** may be applied. The electrical interconnect **130** may comprise first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134** as described above in more detail. By way of example, the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134** may be contact clips or galvanically deposited conductors. In one embodiment, filling of the openings **310**, **311**, **312**, **313**, **314** and forming of the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134** may be accomplished by using the same deposition method. If a continuous layer of conductive material is formed on the upper surface **151** of the electrically insulating material **150**, structuring techniques may be applied to generate the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134**. It is also possible to use wires for forming the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134**. Regarding the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134**, reference is made to the corresponding disclosure above to avoid reiteration. Further, all disclosure including techniques, methods, materials and dimensions as described above in conjunction with FIGS. 1A-2B may be used to manufacture the electronic device **300** shown in FIG. 3E.

FIG. 4 illustrates an alternate embodiment of manufacturing a semiconductor device **400**. In this embodiment, the process may follow the prior embodiment as described in FIGS. 3A-3E. Next, as described previously, the bottom surfaces of the first carrier **110**, the second carrier **120**, the first lead **141**, and the second lead **142** may be coated by solderable coating **161**.

FIGS. 5A-5C exemplify various implementations of an electronic device **500**. The electronic device **500** of FIG. 5A may correspond to the electronic device **100** of FIG. 1D with the exception that the electrically insulating material **150** may be arranged to partly or fully cover the upper surfaces of the first, second, third and fourth electrical interconnects **131**, **132**, **133**, **134**, or, more specifically, the upper surfaces of the first sections **131a**, **132a**, **133a**, **134a** thereof. That way, all external-facing surfaces of the electrical interconnect **130** may be completely covered by the electrically insulating material **150**.

The electronic device **500** of FIG. 5B may correspond to the electronic device **500** of FIG. 5A with the exception that the external-facing upper surface **151** of the electrically insulating material **150** has one or more recesses **155** exposing the electrical interconnect **130**. By way of example, portions of one or more of the upper surfaces of the first sections **131a**, **132a**, **133a**, **134a** of the electrical interconnect **130** may be exposed. The exposed portion(s) may serve as heat sink(s) for dissipating heat generated by the power semiconductor chips **111**, **121**.

The electronic device **500** of FIG. 5C may correspond to the electronic device **500** of FIG. 5A with the exception that the gaps or recesses between the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** may be filled by electrically insulating material **150**.

All disclosure including techniques, methods, materials and dimensions as described above in conjunction with FIGS. 1A-4 may be used to manufacture the electronic

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devices **500** shown in FIGS. **5A-5C**. Reference is made to this disclosure to avoid reiteration.

FIGS. **6A-6B** exemplify implementations of an electronic device **600**. The electronic device **600** of FIG. **6A** may correspond to the electronic device **200** of FIG. **2A** with the exception that the first carrier **110**, the second carrier **120**, the first lead **141** and the second lead **142** may comprise a double layer structure.

More specifically, first chip carrier **110** may, e.g., comprise upper first carrier portion **110a** and lower first carrier portion **110b**, second chip carrier **120** may, e.g., comprise upper second carrier portion **120a** and lower second carrier portion **120b**, first lead **141** may, e.g., comprise upper first lead portion **141a** and lower first lead portion **141b** and second lead **142** may, e.g., comprise upper second lead portion **142a** and lower second lead portion **142b**. The first and second power semiconductor chips **111**, **121** are mounted on and electrically connected to the upper first and second carrier portions **110a**, **120a**, respectively. The lower first and second carrier portions **110b**, **120b** and the lower first and second lead portions **141b**, **142b** may form external contact elements (or external contact pads) of the electronic devices **600** of FIGS. **6A-6B**. The upper carrier and/or lead portions **110a**, **120a**, **141a**, **142a** are electrically connected to the corresponding lower carrier and/or lead portions **110b**, **120b**, **141b**, **142b** by electrically conductive vias **170**. Electrically conductive vias **170** are running through an extended zone of the electrically insulating material **150**. Due to the double layer structure of e.g. the first chip carrier **110**, the second chip carrier **120**, the first lead **141** and the second lead **142**, the thickness of electronic device **600** may typically be greater than the thickness of electronic device **200** of FIG. **2A**.

As a modification to the electronic device **600** of FIG. **6A**, the electronic device **600** of FIG. **6B** may be provided with a continuous layer of electrically insulating material **150** at the upper device surface. As described in conjunction with FIG. **5A**, all external-facing surfaces of the electrical interconnect **130** may be completely covered by the electrically insulating material **150**. All disclosure including techniques, methods, materials and dimensions as described above in conjunction with FIGS. **1A-5C** may be used to manufacture the electronic devices **600** shown in FIGS. **6A-6B**. Reference is made to this disclosure to avoid reiteration.

FIGS. **7A-7B** exemplify implementations of an electronic device **700**. The electronic devices **700** of FIGS. **7A-7B** may correspond to the electronic devices **600** of FIGS. **6A-6B** with the exception that the double layer structure is used as a redistribution structure to customize the footprint of the electronic device **700** to specific needs. More specifically, the upper carrier portions **110a**, **120a** and/or the upper lead portions **141a**, **142a** may be displaced in lateral direction relative to the lower carrier portions **110b**, **120b** and/or the lower lead portions **141b**, **142b**, respectively.

All embodiments described herein may comprise more than two chip carriers and more than two power semiconductor chips. FIG. **8** exemplifies an electronic device **800** comprising, by way of example, three chip carriers **110**, **120**, **180** and three power semiconductor chips **111**, **121**, **181**. The electronic device **800** may be completely encapsulated by the electrically insulating material **150** as shown in FIG. **8** or may have exposed areas of the electrical interconnect **130** as described above with reference to some embodiments. Again, all disclosure including techniques, methods, materials and dimensions as described above in conjunction with FIGS. **1A-7B** may be used to manufacture the electronic

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device **800** shown in FIG. **8**. Reference is made to this disclosure to avoid reiteration.

FIG. **9** illustrates one exemplary method. In step **S1** a first chip carrier is provided.

In step **S2** a second chip carrier is provided, wherein the second chip carrier is isolated from the first chip carrier.

In step **S3** a first power semiconductor chip is mounted on the first chip carrier, whereby the first power semiconductor chip is electrically connected to the first chip carrier.

In step **S4** a second power semiconductor chip is mounted on the second chip carrier, whereby the second power semiconductor chip is electrically connected to the second chip carrier.

In step **S5a** an electrically insulating material configured to at least partially surround the first power semiconductor chip and the second power semiconductor chip is formed.

Thereafter, in step **S6a**, an electrical interconnect configured to electrically connect the first power semiconductor chip to the second power semiconductor chip is applied.

According to another example as illustrated in FIG. **10**, steps **S1** to **S4** are performed.

In step **S5b** an electrical interconnect configured to electrically connect the first power semiconductor chip to the second power semiconductor chip is applied, wherein the electrical interconnect comprises a contact clip.

In step **S6b**, an electrically insulating material configured to at least partially surround the first power semiconductor chip and the second power semiconductor chip is formed. In accordance with one embodiment, step **S6b** may be performed before step **S5b**. In accordance with another embodiment, step **S6b** may be performed after step **S5b**.

According to another example as illustrated in FIG. **11**, steps **S1** to **S4** are performed.

In step **S5c** an electrical interconnect configured to electrically connect the first power semiconductor chip to the second chip carrier is applied.

In step **S6c** an electrically insulating material configured to at least partially surround the first power semiconductor chip and the second power semiconductor chip is formed by lamination. In accordance with one embodiment, step **S6c** may be performed before step **S5c**. In accordance with another embodiment, step **S6c** may be performed after step **S5c**.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. By way of example, the first electrical interconnect **131** described above may, e.g., be a bonding wire in some embodiments. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

What is claimed is:

1. A method of manufacturing an electronic device, the method comprising:

providing a first chip carrier;

providing a second chip carrier, wherein the second chip carrier is isolated from the first chip carrier;

mounting a first power semiconductor chip on the first chip carrier, thereby electrically connecting the first power semiconductor chip to the first chip carrier;

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- mounting a second power semiconductor chip on the second chip carrier, thereby electrically connecting the second power semiconductor chip to the second chip carrier;
- forming an electrically insulating material configured to at least partially surround the first power semiconductor chip and the second power semiconductor chip; and
- after forming the electrically insulating material, applying an electrical interconnect configured to electrically connect the first power semiconductor chip to the second power semiconductor chip, wherein applying the electrical interconnect comprises:
- forming a first via in the electrically insulating material, the first via exposes a portion of the second chip carrier; and
 - filling the first via by using galvanic deposition.
2. The method of claim 1, wherein forming the electrical interconnect comprises:
- forming a second via in the electrically insulating material, the second via exposes a portion of a first contact pad arranged on a top main face of the first power semiconductor chip; and
 - filling the second via by using the galvanic deposition.
3. A method of manufacturing an electronic device, the method comprising:

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- providing a first chip carrier;
- providing a second chip carrier, wherein the second chip carrier is isolated from the first chip carrier;
- mounting a first power semiconductor chip on the first chip carrier, thereby electrically connecting the first power semiconductor chip to the first chip carrier;
- mounting a second power semiconductor chip on the second chip carrier, thereby electrically connecting the second power semiconductor chip to the second chip carrier;
- forming an electrically insulating material configured to at least partially surround the first power semiconductor chip and the second power semiconductor chip; and
- after forming the electrically insulating material, applying an electrical interconnect configured to electrically connect the first power semiconductor chip to the second power semiconductor chip, wherein applying the electrical interconnect comprises:
- forming a via in the electrically insulating material, the via exposing a portion of a first contact pad arranged on a top main face of the first power semiconductor chip; and
 - filling the via by galvanic deposition.

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